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An economic model of guerrilla warfare

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AN ECONOMIC MODEL OF GUERRILLA WARFARE*

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This paper draws on the guerrilla warfare literature so as to synthesize and to describe the dynamics of the initial stages of a guerrilla war against an established government. It combines two classical economic models, the Solow growth model and the Ricardian model of economic rents, with two classic studies of guerrilla warfare by T. E. Lawrence and by Mao Tse-tung. The transitional stages of the guerrilla warfare are modeled as conflict over control of the real line. Four different Ricardian distribution functions describe the country: the *resources* the guerrillas can extract from territory under their control; the *porosity* of the country, indicating the guerrilla's ability to obtain weapons; the government's *ability to tax;* and the *mobility* the guerrillas. Depending on initial conditions, the course of the guerrilla war could take one of several paths. One is a direct movement to a stable equilibrium independent of the initial conditions. Another is a situation in which for the guerrillas to make a successful transition to the second stage via the dynamics of the process they have to reach a certain critical level of capability. Finally, the third path involves cyclical motion, with alternating positions of the guerrillas and the government in the evolution of the war. This model, while simple, appears to be consistent with the historical pattern of guerrilla wars, a key parameter in the model being porosity.

INTRODUCTION

Guerrilla warfare has been the subject of studies over a long period, many by master practitioners of the art. In this century, T. E. Lawrence (1936), Mao Tse-tung (1954, 1978), and Ernesto (Che) Guevara (1985), have all written books on this subject based on their experiences as leaders of guerrilla forces. These books range from mystical reflections on the nature of man to practical details such as the necessary contents of a knapsack and the best way to destroy railroad tracks. They reflect the personalities and special experiences and circumstances of these men. This paper is an attempt to draw on this body of literature so as to synthesize and to describe the dynamics of the initial stages of a guerrilla war.

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As noted by Guevara, guerrilla wars can be divided into two types. The first type is an armed group against an established government. Examples include the Mexican Revolution, the wars in Indochina and Algeria against the French, Greece, Malaya, the Cuban Revolution, and the current war in Afghanistan. The second type consists of actions in support of regular armies in the field. Examples include the Peninsular Campaign against Napoleon; the Arab revolt in World War I; partisan actions behind German lines in World War II; and some of the action against the Japanese in the Philippines, China, and Indochina. Having defined the two categories, it should be noted, first, that the two are not always mutually exclusive and, second, that the classification may depend on the viewpoint of the observer. From the allied point of view, the revolt in the desert was an irregular operation in support of British forces, but, from the point of view of the Arabs it was a revolt against the Turks. This paper will concentrate on the first type of guerrilla war since the focus will be on the initial viability of such insurrections. If the guerrilla war is being supported as part of a larger operation, the issues involved are very different.

Since Mao, it is almost accepted doctrine that a guerrilla war must pass through three stages. The first stage is a strategic defensive one in which the guerrillas attempt to establish a force but not necessarily hold and occupy territory. The second stage is one of stalemate. The third stage is that of the strategic offensive which ends the war. The third stage will not be addressed in this paper for two reasons. First, if it occurs, it involves a significant structural change in the relationships of the agents that is beyond the scope of this study. Second, it is not clear that all guerrilla wars progress into the third stage. Rather, it seems that at some key point in the conflict members of the government, behaving in a rational manner, are able to foresee the inevitable and to depart, triggering a rapid collapse of the government forces. Examples of such instances are Mexico in 1911, when Porfirio Diaz fled to Paris with his army intact; Cuba in 1959, when Fulgenico Batista fled to the United States and eventually to Portugal; and Vietnam, where the government forces collapsed and fled the battlefield, leaving behind weapons, fuel, and ammunition.

THE MODEL

In our efforts to model the dynamics of guerrilla warfare we will combine two classical economic models, the Solow growth model and the Ricardian model of economic rents with two classic studies of guerrilla warfare, T. E. Lawrence's *Seven Pillars of Wisdom,* and Mao Tse-tung's *On the Protracted War.* We will make the Ricardian assumption that a country can be described by distribution functions defined on a closed interval of the real line. While such an assumption is far from the poetry of *Seven Pillars of Wisdom,* it is certainly in the spirit of Mao's observation that "... the people are the sea and the guerrillas are the fish." We are, in effect, just adding some mathematical structure to this useful metaphor.

The transitional stages of the guerrilla warfare will be modeled as conflict over control of the real line, representing different distribution functions. The question is under what conditions a stable equilibrium exists. We will interpret the equilibrium as the second of Mao's three stages. At this point it is useful to introduce some notation. (For other mathematical models of guerrilla warfare see Deitchman, 1962; Schaffer, 1967; Stahel, 1975; and Intrilligator and Brito, 1988.)

x = territory controlled by the guerrillas

y = ratio between the guerrilla and the government forces

v_1 = guerrilla resources devoted to fighting

u_1 = guerrilla resources devoted to training

v_2 = government resources devoted to fighting

u_2 = government resources devoted to training

We will assume that the country can be described by four Ricardian distribution functions on the interval [0,1]. These functions are defined over attributes of the economy rather than the distribution of random variables (e.g., Mirrlees, 1972). The first distribution function, $R(x)$, is a measure of the *resources* the guerrillas can extract from territory under their control. It will be assumed that $R'(x) > 0$, so that an increase in territory controlled by the guerrillas increases the resources available to the guerrillas. One must be careful in interpreting this term. It does not mean that the guerrillas attempt to control physical ground permanently. They may fight and then run in order to avoid unnecessary losses by not attempting to control ground. Mao justifies such tactics by the statement, "One eats first and then relieves oneself; does one eat in vain." (Mao, 1954, v. 2, p. 235.) More elegantly, Lawrence states "We might be a vapor, blowing where we listed. Our kingdom lay in each man's mind, and as we wanted nothing material to live on, so we offer nothing material to the killing." (Lawrence, 1936, p. 192.)

The second distribution function, $P(x)$, is a measure of the *porosity* of the country. Porosity will be defined as the guerrilla's ability to obtain weapons. It will be assumed that $P'(x) > 0$, so that an increase in territory controlled by the guerrillas increases the ability of the guerrillas to obtain weapons. It may be the case that the guerrillas are able to manufacture some of the necessary weapons. Historically, however, the ability to import weapons has been an important factor in the viability of guerrilla wars. In the American Revolution the ability to import gunpowder and firearms through St. Eustatus (Tuchman, 1988) was crucial. Similarly, in the Mexican Revolution, the ability to import weapons from the United States was crucial to the success of Pancho Villa's forces (Rice, 1988). In recent times, the Afghan Mujahadeen's ability to receive weapons through Pakistan has been an important factor in their success. The interpretation of the porosity variable should not be limited to transborder shipments of arms; in many cases arms can be obtained directly from corrupt or sympathetic government forces. For example, Chapelle has estimated that 85 per cent of Castro's arms and ammunition were obtained from Batista's forces in one way or another (Chapelle, 1960).

The third distribution function, $T(x)$, is a measure of the government's *ability to tax.* It will be assumed that $T'(x) < 0$, so that an increase in territory controlled by the guerrillas decreases the ability of the government to tax.

The three distribution functions define the budget constraints of the two parties to the conflict, the guerrillas and the government, which can be stated

$$P(x) + R(x) = v_1 + u_1 \tag{1}$$

$$T(x) = v_2 + u_2. \tag{2}$$

The fourth distribution function necessary to describe a guerrilla war is a measure of *mobility*, M(x). This function depends not only on the natural terrain of the country and infrastructure, but also on the technology. In 1917, the desert was almost ideal guerrilla terrain for the Arabs. They were able to attack the Turkish railways and retreat into the desert. Even then, signs of change were visible. In 1918, Turkish aircraft were able to inflict heavy casualties on the Arab forces, and it was necessary to bring in British air support (Lawrence, 1936).

It will be assumed that fighting in the first stage consists of small unit conflicts between the guerrillas and government forces. These forces have been optimized for the prevailing conditions. The government forces will be assumed to be optimally deployed, protecting the population and the transportation and communications network. (Lawrence, 1936, p. 192). However, control on the part of the guerrillas is assumed to be decentralized, with guerrilla commanders making decisions based only on local information. Rice (1988, p.62) states "The general headquarters . . . can set forth the objective it wants them to obtain and lay down the operational and other policies it wants them to follow. But commanders in the field are necessarily allowed a substantial degree of operational autonomy: no general headquarters could make detailed decisions for numerous small units scattered about it knows not where, in circumstances of which it may be unaware . . ." Since the government forces are reacting to guerrilla attacks we will assume that the effectiveness of the government forces depends on the mobility of its forces, as given by M(x). The technology for the change in guerrilla control, x, is assumed to be given by the differential equation.

$$\dot{x} = f(x,y,v_1,v_2), \tag{3}$$

which is assumed to have following partial derivatives

$$\frac{\partial f(x,y,v_1,v_2)}{\partial x} < 0 \tag{4}$$

$$\frac{\partial f(x,y,v_1,v_2)}{\partial y} > 0 \tag{5}$$

$$\frac{\partial f(x,y,v_1,v_2)}{\partial v_1} > 0 \tag{6}$$

$$\frac{\partial f(x,y,v_1,v_2)}{\partial v_2} < 0. \tag{7}$$

These assumptions imply that the guerrillas operate initially in the economically marginal sections of the country, such as desert, mountain, and jungle areas which are advantageous to guerrilla tactics. As the war progresses they are forced to operate in increasingly developed and more open parts of the country with a transportation infrasture that given increased advantage to the government forces.

The process is assumed to be *Markovian*, that is, the change in variables in any one period depends only on current values of the variables and is thus independent of the prior history other than as this history affects current variables. Agents are assumed to be optimizing given resources and information. Then v_1 and v_2 can be solved as functions of the state variables x and y, resulting in the optimal solutions, $v_1^*(x,y)$ and $v_2^*(x,y)$. Substituting into the differential equation (3) leads to the dual transition differential equation for control

$$\dot{x} = f[x,y,v_1^*(x,y),v_2^*(x,y)] \equiv F(x,y) \tag{8}$$

This function is analagous to the indirect utility function in consumer theory (See Varian, 1984). It satisfies

$$\frac{\partial F(x,y)}{\partial y} > 0 \tag{9}$$

The sign of $\frac{\partial F(x,y)}{\partial x}$ is more difficult to determine, since it depends on the relative properties of the derivatives of the distribution functions.

The differential equation that describes the change in the ratio of forces is

$$\dot{y} = g(x,y,\ u_1,u_2), \tag{10}$$

where the partial derivatives satisfy

$$\frac{\partial g(x,y,u_1,u_2)}{\partial y} > 0 \tag{11}$$

$$\frac{\partial g(x,y,u_1,u_2)}{\partial u_1} > 0 \tag{12}$$

$$\frac{\partial g(x,y,u_1,u_2)}{\partial u_2} < 0 \tag{13}$$

This process is similar to a Solow growth model, and it is also assumed to be Markovian (See Solow, 1956). The controls u_1 and u_2 can be solved as functions of the state variables x and y, yielding the optimal solutions $u_1^*(x,y)$ and $u_2^*(x,y)$. Substituting these solutions into the differential equation (10) results in the dual transition differential equation for the force ratio

$$\dot{y} = g[x,y,u_1^*(x,y),u_2^*(x,y)] \equiv G(x,y) \tag{14}$$

In most cases it follows that

$$\frac{\partial G(x,y)}{\partial x} > 0 \tag{15}$$

The sign of $\frac{\partial G(x,y)}{\partial x}$ depends on an assumption concerning returns to scale in training. The exact properties of F(x,y) and G(x,y) depend on the properties of the technologies and distribution functions that represent the conflict.

The microfoundations between the properties of the functions F(x,y) and G(x,y) and the Ricardian distribution functions and technologies are complex and will require additional work beyond the scope of this paper (Brito and Intriligator, 1989).

QUALITATIVE PROPERTIES OF SOLUTION PATHS

This section will investigate the qualitative properties of the models using phase diagrams. The first two cases we will analyze will assume that the functions satisfy

$$F(0,0) = G(0,0) = 0, \tag{16}$$

the Ricardian assumptions that

$$\frac{\partial F(x,y)}{\partial x} < 0 \tag{17}$$

$$\frac{\partial G(x,y)}{\partial y} < 0 \tag{18}$$

and the nonsatiation assumptions that

$$\frac{\partial F(x,y)}{\partial y} > 0 \tag{19}$$

$$\frac{\partial G(x,y)}{\partial x} > 0 \tag{20}$$

Assumptions (17) and (18) are consistent with the guerrillas using the resources with the highest marginal product first, hence the term "Ricardian". Assumptions (19) and (20) mean that the resources have a positive marginal product.

The slope of the function defined by the relationship F(x,y) = 0 is given by

$$\theta'(x) = \frac{dy}{dx}\Big|_{\dot{x}=0} = \frac{\dfrac{\partial F(x,y)}{\partial x}}{\dfrac{-\partial F(x,y)}{\partial y}} \tag{21}$$

and the slope of the function by the relationship G(x,y) = 0 is given by

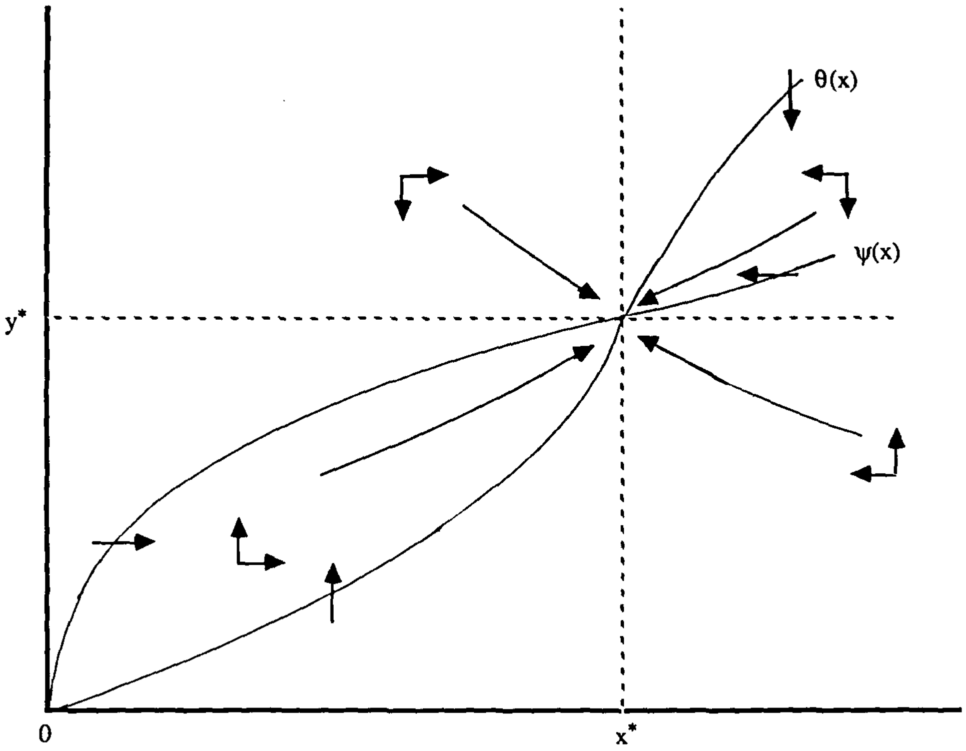

FIGURE 1

$$\psi'(x) = \frac{dy}{dx}\Big|_{\dot{y}=0} = \frac{\frac{\partial G(x,y)}{\partial x}}{\frac{-\partial G(x,y)}{\partial y}} \tag{22}$$

where $\theta(x)$ and $\psi(x)$ are the implicit functions defined by $F(x,y) = 0$ and $G(x,y) = 0$ respectively.

The first case is depicted in Figure 1. It is assumed that an equilibrium point exists and that $\theta'(0) > \psi'(0)$. The equilibrium point is given by (x^*,y^*). The assumption that $\frac{\partial F(x,y)}{\partial x} < 0$ implies that for all $x \leq \theta(x)$, $\dot{x} \geq 0$, while the assumption that $\frac{\partial G(x,y)}{\partial y} < 0$ implies that for all $y \leq \psi(x)$, $\dot{y} \geq 0$. This is the case where initially the increase in the economic resources from increasing x to the guerrillas outweighs the relative decrease in their military advantage. The equilibrium is stable and the guerrillas are able to make the transition into the second stage of a guerrilla war.

The second case is depicted in Figure 2. It is assumed again that an equilibrium point exists. However, it is now assumed that $\theta(0) < \psi(0)$. In this case there are two equilibrium

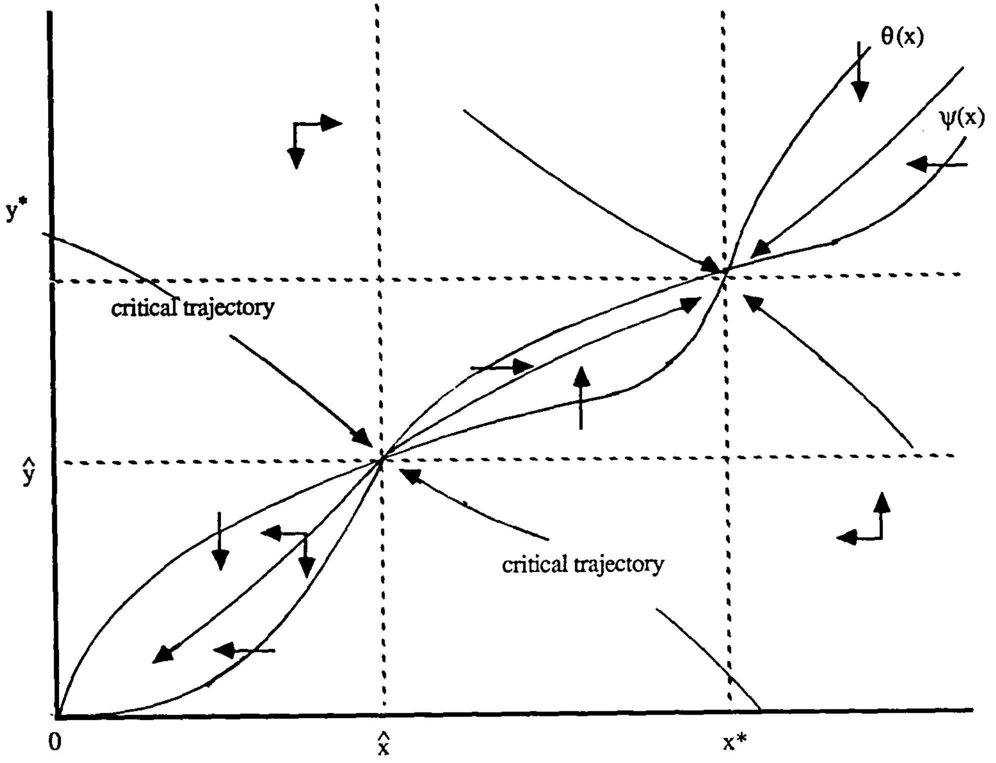

FIGURE 2

points, given by $(\hat{x},\hat{y})$ and (x^*,y^*). The assumption that $\frac{\partial F(x,y)}{\partial x} < 0$ implies that for all $x \leq \theta(x)$, $\dot{x} \geq 0$, while the assumption that $\frac{\partial G(x,y)}{\partial y} < 0$ implies that for all $y \leq \psi(x)$, $\dot{y} \geq 0$. This is similar to the first case. In this case, however, the increase initially in the economic resources available to the guerrillas from increasing x does not outweigh the relative decrease in their military advantage. There are two equilibria, and the first exhibits saddle point instability while the second is stable. However, the guerrillas are able to make the transition into the second stage of a guerrilla war only if the initial conditions are above the critical trajectory in Figure 2.

The third case that we will analyze will assume that the function

$$F(x,y) = 0 \tag{23}$$

for all $x \leq \hat{x}$. Thus, unless the initial conditions are above the critical trajectory that starts at $x = 0$ and $y = \hat{y}$ the outcome will be one that ends at some $x < \hat{x}$, and there will not, in fact, be a successful transition to the second stage of the guerrilla warfare if the initial conditions are above the critical trajectory. The dynamics will be cyclical, and we should observe fluctuations in the fortunes of the two forces. Nonsatiation implies that the equilibrium (x^*,y^*) is stable.

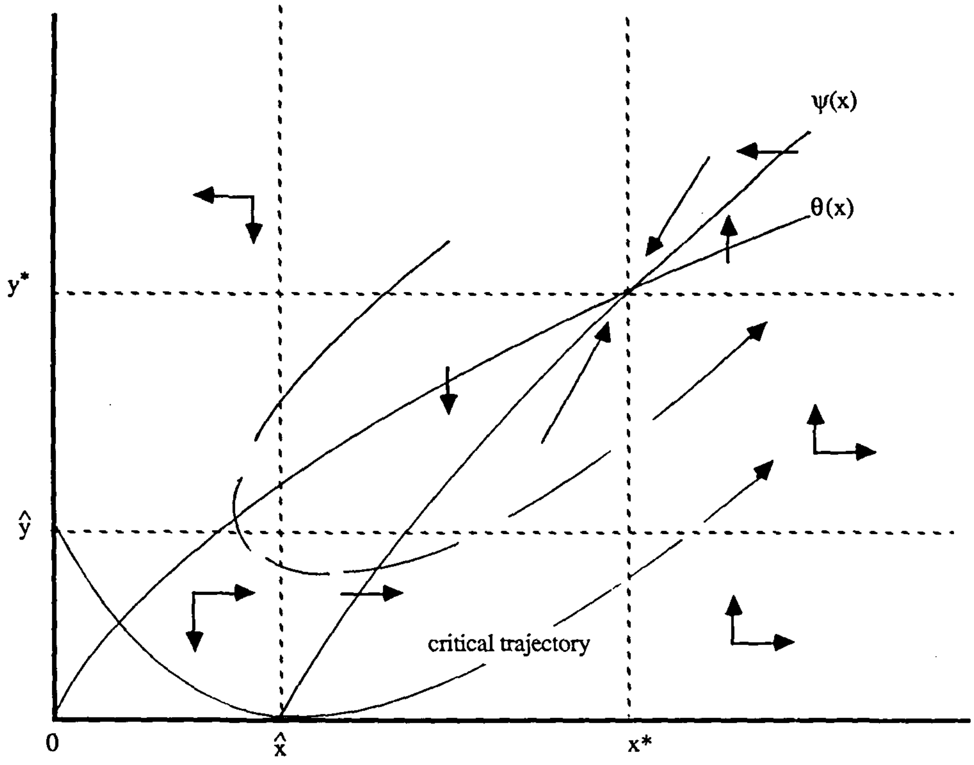

FIGURE 3

Thus, depending on initial conditions, the course of the guerrilla war could take one of several paths. One such path is a direct movement to the second stage of the guerrilla war. Another is a situation in which the guerrellas have to reach a certain critical level of capability to reach the second stage via the dynamics of the process. Finally, the third such path involves cyclical motion, with alternating positions of the guerrillas and the government in the evolution of the war.

CONCLUSIONS

We have formulated an economic model of the transition to the second stage of a guerrilla war based on very general assumptions. With this model it is possible to divide guerrilla wars into three categories. The first category is when the guerrillas can make a successful transition to a stable equilibrium independently of the initial conditions. The second category is when the guerrillas can make a successful transition to the second stage only if the initial conditions are above a critical trajectory. This trajectory leads to an equilibrium point that is a saddle point. There are two equilibria: one is an unstable saddle point and the other is stable. In the third category, the guerrillas can make a successful transition to the second stage only if the initial conditions are again above a critical trajectory. This trajectory, however, leads to an equilibrium point that is stable. The trajectories leading to the equilibrium point will exhibit cyclical behavior.

The model described in this paper is simple, however, it appears to be consistent with the historical pattern of guerrilla wars. There are many important factors, but a key parameter in the model is porosity. The romantic notion of valiant guerrillas fighting the government with homemade weapons does not appear to be valid. All successful guerrilla movements, including those in Arabia, Mexico, China, Indochina, Algeria, South Vietnam, and Afghanistan, have had access to an outside source of weapons. In the cases where the government was able to isolate the guerrillas from outside support, such as in Greece and Malaya, the guerrilla movements failed. The one anomaly may be Cuba, but even in that case Castro's forces were able to obtain weapons from Batista's forces which were corrupt. A government can remain in power if it can control its borders and its military forces. The failure of uprisings in Eastern Europe suggests that, unfortunately, it is not necessary for a government to win the "hearts and minds" of the population. However, winning the hearts and minds of at least a segment of the population may be a necessary condition for the success of the guerrillas. The difference is that, generally, the government can compel military service from the population while the guerrillas cannot.

It is tempting to apply the model in detail to the various recent guerrilla wars. However, in this paper, we will restrict ourselves to two examples; Vietnam and Cuba after the Bay of Pigs. The Vietnam war appears to fall into two of the categories. Pre-Tet, the indigenous forces were unable to achieve a stable equilibrium and were destroyed. This phase of the war would fall into category two of our model. Post-Tet, the fortunes of the guerrilla vacillated, however, they were able to achieve a stable equilibrium with strong support from North Vietnam. This phase of the war would fall into category three of our model. In the case of Cuba after the Bay of Pigs, the model suggests that had the anti-Castro guerrillas received sufficient initial support they could have achieved the second stage and could have possibly overthrown Castro. The United States was in a position to provide the logistical support that was necessary had it chosen to do so.

It should be noted that the model does not explain the transition from the second to the third stage. If this transition occurs, it involves a significant structural change in the relationships of the agents that is beyond the scope of this study. However, it is not clear that all guerrilla wars progress into the third stage. Rather, it seems that at some key point in the conflict members of the government, behaving in a rational manner, are able to foresee the inevitable and to depart, triggering a rapid collapse of the government. As already noted, examples of such a departure followed by a rapid collapse of the government include Mexico, Cuba, and Vietnam.

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